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by

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INTRODUCTION

The Douglas-fir tussock moth [1] (DFTM) periodically defoliates ornamental trees and natural stands of Douglas-fir, [2] true firs, [3] and spruce [4] in the western United States. Tussock moth populations reach outbreak numbers at irregular intervals, and are capable of maintaining these numbers for approximately two to three years in forest stands before collapse (Wickman, Mason and Thompson 1973). Infestations in ornamental trees may persist for more than three years. During these periods, defoliation by the DFTM can seriously retard tree growth, cause top-killing, and tree mortality. Defoliation of ornamental trees is particularly unsightly, detracting from land values and causing extreme concern to homeowners.

In recent years, a need to determine the efficacy of ground applied insecticides to protect individual high-value trees from defoliation by the DFTM has been recognized. Initial ground trest with four insecticides for the purpose of comparing effectiveness and providing data for possible Environmental Protection Agency registration were undertaken in Montana in 1976 (Kohler 1976). This reported test is considered a continuation of the 1976 study with a change in geographic location and expanded tests with the insecticide Dimilin.[5]

[1] *Orgyia pseudotsugata* McD., Lepedoptera: Lymantriidae
[2] *Pseudotsuga menziesii* (Mirb.) Franco
[3] *Abies* spp.
[4] *Picea* spp.
[5] Manufacturers trade name

The objective of this study was to evaluate the effectiveness of several insecticidal preparations, applied from the ground, in reducing DFTM larval populations. Information obtained, in part, will eventually be used to determine optimum application rates and efficacy of test chemicals for possible registration as ground applied insecticides.

LOCATION OF STUDY

In 1977, a suitable DFTM population existed in Medio Dia Canyon, ca. 35 miles southwest of Santa Fe, New Mexico on the Santa Fe National Forest. Elevation of the test area was 6,460 feet. The DFTM was confined to a limited area, placing some constraints on study plot location. Douglas-fir and white fir [6] on the north-facing side of the canyon bottom maintained the DFTM population. Ponderosa pine [7] and scattered southwestern white pine [8] occupied the south-facing and higher north-facing slopes. The DFTM was first observed in the canyon in 1976, where 50 to 60 acres of Douglas-fir and white fir were severely defoliated.

METHODS

Materials and Formulations

Four insecticides (pyrethrin, acephate, carbaryl, and diflubenzuron at various rates) were tested. (Table 1) All insecticidal formulations were diluted with water. In two diflubenzuron treatments, ethylene glycol was added as a surfactant and anti-evaporant.

Design

Seven insecticidal treatments plus a control (no treatment) were randomly assigned to 80 trees (10 replicates for each treatment). Test trees were Douglas-fir and white fir, 20 to 45 feet in height, sufficiently separate to discount insecticidal drift between trees. All test trees exhibited little or no 1976 defoliation.

[6] *Abies concolor* (Gord. and Glend.) Lindl.

[7] *Pinus ponderosa* Laws.

[8] *Pinus strobiformis* Engelm.

TABLE 1 - Insecticidal Treatments and Application Rates Tested

Treatment	Insecticide	Trade Name	Application Rate*
1	pyrethrin	Pyrocide Growers' Spray	1/10 lb. active
2	acephate	Orthene 75S	1/2 lb. active
3	carbaryl	Sevin WP	1/2 lb. active
4	diflubenzuron	Dimilin 25 WP	1/16 lb. active
5	diflubenzuron	Dimilin 25 WP	1/8 lb. active
6	diflubenzuron	Dimilin 25 WP	1/16 lb. active plus 10% ethylene glycol
7	diflubenzuron	Dimilin 25 WP	1/8 lb. active plus 10% ethylene glycol

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* Rate per 100 gal. water

Design layout followed a completely randomized analysis of variance. Tukey's procedure for multiple comparisons of treatment means was used to compare the effectiveness of various treatments in reducing DFTM larval populations. Corrections for natural mortality were computed.

Evaluation

Larval sampling followed Mason's (1970) technique. Three 15-inch branch samples were taken from the mid-crown of each tree with a catch basket, equipped with a pole pruner. Two samples were taken from the inner portion of the crown and one sample from the outer crown. Larvae were removed from the branch samples to a drop cloth and tallied. Length and width of the branches were measured. Larval populations were expressed as larvae per 1,000 sq. inches of foliage.

DFTM larval populations were sampled immediately prior to insecticidal treatments, 2 and 7 days after the pyrethrin, acephate, and carbaryl treatments; and 7 and 14 days after the diflubenzuron treatments. Control trees were sampled prior to, and 2, 7, and 14 days after insecticidal treatments.

Application of Treatments

Insecticidal treatments were scheduled to commence after larvae had dispersed throughout the foliage and established feeding sites. A truck mounted Bean hydraulic sprayer (model 1010A) equipped with a FMC 29 adjustable nozzle with D-9 orifice was used to apply the insecticides (Figure 1). At 200 psi pump pressure, the sprayer used approximately 3.5 gallons per minute. Test trees were sprayed to the point of runoff.

Insecticides were mixed at the experimental site (Figure 2). Water for dilution was drawn from a nearby stream.

RESULTS

Prespray larval sampling began on June 6, 1977. Eighty percent of DFTM larvae were in the second instar and 20 percent in the first instar (Table 2). Insecticide application commenced on June 7. Weather conditions were ideal during the spray period. Wind conditions permitted spraying into the early afternoon.

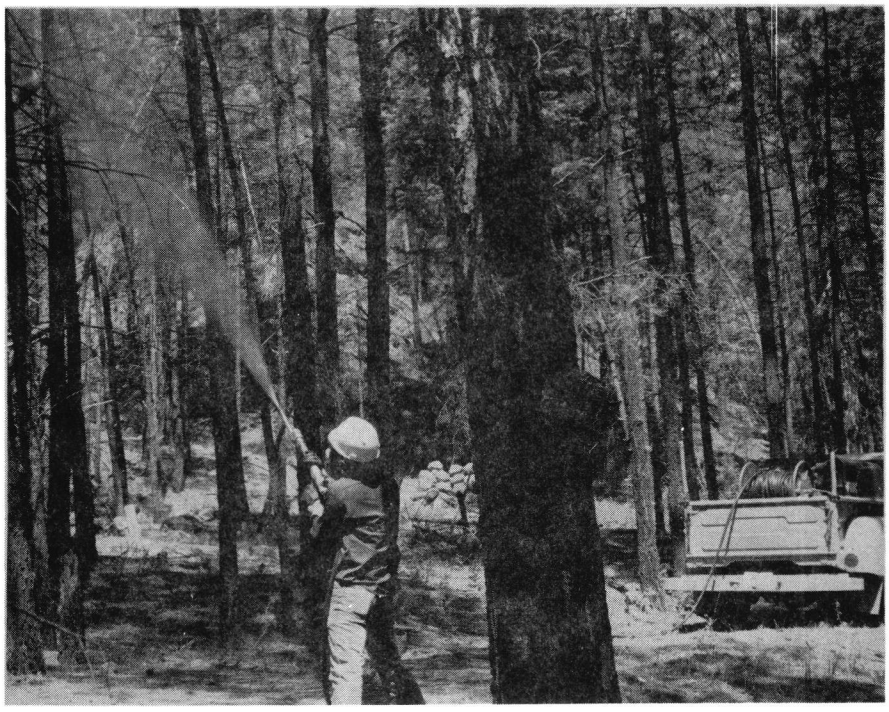

Figure 1. Insecticides were applied with a FMC 29 adjustable nozzle.

Figure 2. Insecticides were mixed in the Bean 1010A tank at the test site.

Estimates of larval densities on test trees were made prior to, and 2, 7 and 14 days after treatments. At fourteen days post spray, 50 percent of the DFTM larvae were in the fourth instar.

An analysis of variance followed by a Tukey's test to compare the effectiveness of various treatments in reducing larval populations indicated all insecticidal treatments caused significantly ($\alpha = 0.05$) greater mortality than natural mortality on all post spray sampling dates. No significant mortality differences could be determined between insecticidal treatments (Table 3). Prespray larval population densities for the eight test tree groups were not significantly differenct at the 0.05 level.

Corrections for natural mortality were made following the procedure of Simmons and Chen (1975). Confidence limits were established around the corrected percent mortality figures (Table 4). The corrected mortality estimates in Table 4 may be conservative. Due to the small sample size (10 trees/test), this method may be statistically biased causing an underestimation of percent mortality.

DISCUSSION

All insecticides (pyrethrin, acephate, carbaryl, and diflubenzuron), at the rates tested, statistically appeared to have equal effectiveness in reducing DFTM larval populations. Results of the acephate and diflubenzuron tests indicate a greater efficacy at the later sampling dates when compared with the carbaryl and pyrethrin tests.

No estimate of foliage protection was made. However, the new growth was severely damaged on many test trees at two days post spray (Figure 3). Adjacent unsprayed and control trees suffered severe defoliation of new and old growth in parts of the test areas. DFTM larval densities in the test area were extremely high. Prespray means for the ten tree treatment groups ranged from 157 to 331.5 larvae per 1000^2 inches of foliage (20 percent first and 80 percent second instar). The larval density on the control trees was 83.9 DFTM per 1000^2 inches of foliage (50 percent 3rd and 50 percent 4th instar) post spray. Generally, an outbreak condition exists if DFTM larval populations exceed 20 per 1000^2 inches of foliage. These epidemic conditions hindered the effectiveness of the insecticidal test. Considerable variation was encountered between test trees, some of which could be attributed to unusually high larval migration and starvation. Fourteen days after spray, larval populations on the control trees were down 74.7 percent over prespray samples. Considering the epidemic conditions, this ground applied insecticide project may be considered a severe test for those insecticides used.

TABLE 2 - DFTM Larval Instars Encountered During Sampling Periods *

PRESPRAY	2 DAYS POSTSPRAY	7 DAYS POSTSPRAY	14 DAYS POSTSPRAY
20% 1st instar 80% 2nd instar	100% 2nd instar	8.3% 2nd instar 83.3% 3rd instar 8.3% 4th instar	50% 3rd instar 50% 4th instar

* determined by head capsule measurement

TABLE 3 - DFTM Larval Population Density Reduction Expressed As Mean Percentage Mortality [1/]

Insecticide [2]	2 Days Postspray [3]	7 Days Postspray	14 Days Postspray
pyrethrin 1/10# ai	95.53 a	84.11 a	
acephate 1/2# ai	89.98 a	97.41 a	
carbaryl 1/2# ai	99.27 a.	97.16 a	
diflubenzuron 1/16# ai		91.81 a	97.99 a
diflubenzuron 1/8# ai		93.01 a	94.24 a
diflubenzuron 1/16# ai + 10% ethylene glycol		84.73 a	96.58 a
diflubenzuron 1/8# ai + 10% ethylene glycol		89.51 a	98.58 a.
controls	30.42 b	45.94 b	70.24 b

Any two means not subtended by the same letter are significantly different as determined by a Tukey's test at the 0.05 level of significance.

1 uncorrected for natural mortaltiy

2 active ingredient per 100 gal. water

3 carbaryl was actually sampled 3 days after spray

TABLE 4 - Results of the DFTM Ground Applied Pesticide Test

Insecticide[1]	$\bar{X}$ Larval Density/1000[2] Foliage Postspray[2]				Percent Reduction From Prespray			Percent Mortality Corrected[3]		
	Pre-spray	2 Day	7 Day	14 Day	2 Day	7 Day	14 Day	2 Day	7 Day	14 Day
pyrethrin 1/10#ai	189.8	12.6	17.9	----	93.4	90.6	----	90.3± 9.6	81.5±23.1	-----
acephate 1/2#ai	192.9	21.2	3.9	----	89.0	98.0	----	84.1±16.5	96.1± 4.2	-----
carbaryl 1/2#ai	182.6	1.9	2.9	----	99.0	98.4	----	98.6± 2.2	96.9± 3.7	-----
diflubenzuron 1/16#ai	292.4	----	15.4	4.2	----	94.7	98.6	------	89.8±10.6	94.5± 6.3
diflubenzuron 1/8#ai	157.0	----	7.4	2.9	----	95.3	98.2	------	90.8± 7.3	92.5± 7.1
diflubenzuron 1/16#ai + 10% ethylene glycol	222.2	----	32.5	5.2	----	85.4	97.7	------	71.3±23.3	90.9± 8.2
diflubenzuron 1/8#ai + 10% ethylene glycol	176.4	----	12.5	3.0	----	92.9	98.3	------	86.1±11.6	93.3± 8.2
Control	331.5	229.1	168.5	83.9	30.9	49.2	74.7	------	------	------

1 active ingredient per 100 gal. water

2 10 trees per group

3 procedure of Simmons and Chen (1975), 95% confidence level

Figure 3. New growth on this white fir branch was severely damaged by 2nd instar DFTM larve.

Results indicate all insecticides tested are effective in reducing DFTM larval population. Registration of these insecticides with the Environmental Protection Agency should be pursued to provide consumers with effective means of combating DFTM damage.

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